Weather Monitoring Telemetry System Based on Arduino Pro Mini With Antenna Tracker Using Transceiver Module SV651 and SV611

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ABSTRACT
The progress of space technology in various countries is increasing rapidly. In Indonesia, there is a Non-Government Organization Ministry of Indonesia who carries out government duties in the field of aerospace research, development and utilization. The institute is known as LAPAN (National Institute of Aeronautics and Space), which has four main fields namely remote sensing, aerospace technology, space science and aerospace policy. One of the main areas that are important and needed by society is weather monitoring. The weather is always changing in a short time and make it difficult to predict using human senses. Weather monitoring can be performed by considering the parameters of the atmosphere. However, LAPAN still uses weather monitoring tools purchased from Japan to read those parameters. The main objective of this study is to develop a weather monitoring system related to parameters in the atmosphere and that system can transmit data over long distances in real-time using 433 MHz radio frequency and it is equipped with an antenna tracker. In this study, data have been sent using the SV611 module and received by the SV651 module. We have used Arduino pro mini as the main control system that transmits atmospheric data from the sensor such as temperature, humidity, air pressure, wind direction, wind speed, latitude, longitude, and altitude. Data received subsequently have been recorded and displayed using a graphical user interface on a personal computer. The experimental results show that the system can monitor and transmit atmospheric data using radiofrequency with a maximum transmission range of 12.17 km above sea level. The tracker antenna can move horizontally by 0-360 ° and vertically by 0-90 ° following load transfer when it is flown. The GUI can display and save data on a Personal Computer (PC) in real-time.

Keywords: *Weather, Atmosphere, SV611, SV651, Antenna tracker, Arduino pro mini, Graphical user interface*

1. INTRODUCTION

In the modern era, many people use and apply advance technology in many areas such as aeronautical and astronautical technology. Indonesia known as the island nation and as a maritime country should be able to meet the needs of technology in the field of aviation and aerospace. Technology that should be developed in Indonesia right now is the technology in the field of balloon payloads. The technology focuses on collecting data in the atmosphere in the form of parameters such as air pressure, temperature and humidity. In other words, the balloon payloads technology is an important instrument used in observing weather and climate conditions [1].

The utilization of this technology requires a balloon flown and a device to detect the movement of the balloon called tracker antenna. When the balloon release to the atmosphere, there is a load comprised of a temperature sensor, humidity sensor, air pressure sensor, and also a GPS used to read and transmit parameter data in the atmosphere and detect the location as well as the altitude (altitude) so that the tracker antenna can perform tracking automatically [1]. This automatic tracking ability influences the control of objects when moving and can monitor balloon loads by telemetry by knowing their exact and accurate position. However, in Indonesia to launch or release the balloon payload has used ground station antenna system, where the control is manually performed or conventional. This method can cause data received by the antenna inaccurate because it relies on the operator in positioning and direction of movement of the object. Estimates search will become a weaker position when the object is at a long distance and high speed. Moreover, the system uses payloads purchased from Japan so that when they conduct atmospheric monitoring, they must buy the expensive payloads.

In this paper, we create and develop a monitoring system of atmospheric parameters wirelessly using module SV611 and SV651 with a frequency of 433 Mhz. We also use Arduino Pro Mini as the main controller sending data from some sensors such as temperature and humidity sensors, pressure sensors, and GPS sensors. The system equipped with an antenna automatic tracking system is then stored and displayed using the Graphical User Interface on the computer.

The remainder of this paper is structured as follows. The components comprising the system are explained in section II. Section III offers system design. Result and Discussion are presented in section IV. The last section is the conclusion.

2. METHOD

2.1. Components of the System

The components comprising the system will be flown to the atmosphere at an altitude of 0 km to 560 km above the surface of the Earth. The atmosphere is composed of several layers distinguished by some characteristics such as gas composition, temperature, and pressure. The transition between layers is gradual [2].

The atmospheric layer consists of 5 layers namely the Troposphere (altitude 6-10 km), Stratosphere (altitude 20-50 km), Mesosphere (altitude 50-85 km), Thermosphere (altitude 85-690 km), and Exosphere (altitude more than 690 km). The atmospheric layer that most influences weather conditions on the surface of the earth are the Troposphere to Tropopause [3].

Tropopause (10-20 km altitude) is the boundary layer between the troposphere and the stratosphere. Tropopause layer is marked by temperature inversion conditions along with rising altitude. The uniqueness of the Tropopause layer can be observed using Rawinsonda Technology [3].

Figure 1 Arduino Pro Mini

2.1.1. Antenna

The antenna is a device capable of transmitting and receiving electromagnetic waves in the air through radio telemetry. Transmitting an electromagnetic wave displacement flow through the transmitter antenna. The reception is the process of receiving electromagnetic waves flown through the receiver antenna [4].

A directional antenna is a type of antenna radiating and receiving electromagnetic wave signals from one or two directions. While the omnidirectional antenna is a type of antenna that can radiate and receive electromagnetic wave signals from any direction [5]. Antenna implements a wireless communication system known as wireless where the cast has a great distance with good quality [6].

2.1.2. Antenna tracker

Antenna tracker is a tool that is useful as a tracer movement following the signal source. The device can follow the direction of the signal moves through the source of the tracked signal [7]. This tracker can move in two ways namely based on point coordinates of the global positioning system (GPS) and the strength of the received signal power [8].

In principle, the tracker antenna can move based on the horizontal angle (azimuth) and vertical angle (elevation) [9]. using GPS, antenna tracker can determine the data in the form of longitude (distance) from the horizontal or azimuth angle and show the data in the form of latitude from the vertical angle of elevation.

2.1.3. Arduino Pro Mini

Arduino Pro Mini is intended for semi-permanent installations on objects. This allows the use of various types of connectors or direct solder cables [10]. Arduino Pro Mini is designed so that the user can use a reset with software running on a computer connected by Arduino. One six-pin pin header is connected to the reset line of the ATmega328 through a 100 nF capacitor. This pin is connected to a hardwire control line of the converter of USB-to-serial connected to the header.

There are two versions of the Arduino Pro Mini. First, Arduino Pro Mini runs at voltage levels of 3.3V and 8 MHz, secondly, runs at voltage levels at 5V and 16 MHz. Arduino pro-mini-physical form can be presented in Fig. 1.

Figure 2 SHT 31 Sensor

Figure 3 BMP180 Sensor

2.1.4. SHT 31

The relative humidity is the ratio of the partial pressure of water vapour into water vapour pressure in equilibrium at a certain temperature. It requires less steam to achieve high relative humidity at low temperatures and low moisture. The relative humidity sensor used is SHT-31D [11].

The SHT-31D sensor as shown in Fig. 2 is a premium grade digital humidity and temperature sensor from the Sensirion vendor. This is the original version of the DHTx temperature and humidity sensor. SHT-31D has been equipped with I2C communication that does not require a lot of wires and can use many sensors in the microcontroller or readers. These sensors can work at a voltage of 2.4V to 5.5V, which means very good for Arduino, NodeMCU, to the Raspberry Pi.

2.1.5. BMP 180

The atmospheric pressure sensor is a transducer to measure the pressure exerted by the weight of air in Earth's atmosphere. In almost all circumstances estimated at close to atmospheric pressure hydrostatic pressure is caused by the weight of air above the measurement point. The sensor used to measure air pressure is the BMP180 module from Adafruit which can take measurements from 300 hPa to 1100 hPa or altitudes of 9000m to -500m from sea level with resolutions up to 0.003 hPa / 0.25m. This sensor is also capable of measuring temperatures from -40 ° C to +85 ° C [12]. The physical form of the BMP180 sensor is presented in Fig. 3.

2.1.6. Modul GPS Ublox NEO-6M

Global Positioning System (GPS) is a satellite navigation system developed and introduced by US DOD (United States Department of Defense). GPS allows the user to locate the geographic position ourselves in terms of latitude, longitude, and altitude above sea level. So wherever we are on this earth, we can know our exact position [13].

Figure 4 GPS Sensor

Figure 5 SV611 Transmitter

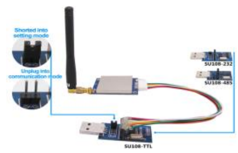

Figure 6 SV651 Receiver

GPS sensors used for this research are Ublox NEO 6M module with a horizontal accuracy of <1 m, accuracy of measurement speeds up to 0.1m / s, and course measurement accuracy up to 0.5 degrees. Speed and course measurement data are used as the atmospheric parameters wind speed and wind direction. The physical form of the GPS Module can be seen in Fig. 4.

2.1.7. Modul SV611 dan SV651

SV611 as shown in Fig. 5 is an application of highly-integrated RF transceiver device that adopts the high-performance Si4432. SV611 provides good sensitivity, 100mW output power to achieve long RF range and reliability of RF communication. To keep away disturbance, SV611 has 40 frequency channels and configurable Net ID. SV611 is flexible but easy to use, it comes with many parameters, such as frequency, data rate, output power, Net ID, Node ID. Users can configure the parameters through a PC or customer’s device [14].

SV651 presented in Fig. 6 is an Industrial class & highly-integrated RF transceiver module that adopts the high-performance Si4432. TTL / 232 /485 can be chosen corresponding to SV651-TTL / SV651-232 / SV651-485. SV651 provides good sensitivity, 500mW output power to achieve long RF range and reliable RF communication. To reject the disturbance, SV651 has 40 frequency channels and configurable Net ID. SV651 is flexible but easy to use, it comes with many parameters, such as frequency, data rate, output power, Net ID, Node ID [15].

Figure 7 Stepper Motor

Figure 8 DC Motor

2.1.8. Stepper Motor

Stepper motor is a motor driven by pulses so that it has electromagnetic properties, which can convert electrical pulses into mechanical motion energy. In the stepper motor, there is a coil on the stator while the rotor is a permanent magnet. The movement of a stepper motor moves by step or angle so that it can more easily adjust the position. Stepper motor is divided into 3 types namely variable reluctance (VR), permanent magnet (PM), and hybrid [16].

The movement has a 45 degree or 90-degree step rotation. Whereas the hybrid type of stepper motor has a combination of VR and PM type stepper, which in its movement can have a step of 360 degrees / 200 or equal to 1.8 degrees to be able to reach 3.6 - 0.9 degrees [16][17]. The physical form of the stepper motor is presented in Fig. 7.

2.1.9. Motor DC

DC motor as shown in Fig. 8 is a type of electric motor that converts electrical energy into mechanical energy which can turn electricity into motion influenced by rotating rotors. The working principle of this motor is given a current when the electric field will exert a force, which is exactly what style will provide rotary power to the coil [18].

This type of dc motor was chosen because it functions as a horizontal drive, shaped from the azimuth angle of the tracker antenna which has a load of reflector antennas.

2.1.10. Arduino Mega

Arduino Mega 2560 presented in Fig. 9 is a microcontroller that uses ATmega2560 microcontroller ic. Arduino Mega 2560 has 54 digital I / O pins with 16

Figure 9 Arduino Mega 2560

Figure 10 Rotary Encoder

analog inputs. This type of Arduino has more space using a 32bit RAM system [19].

2.1.11. Rotary Encoder

Rotary Encoder is an electronic component that functions as monitoring the movement and position of a rotating motor shaft. In general, rotary encoders use optical sensors to generate serial pulses, where pulses are interpreted as movement, position and direction. So that the rotation angle position on the shaft can read and will be processed into digital data by the rotary encoder in the form of the pulse width. Initial data obtained in the form of the angular position will be processed by the controller and will get new data in the form of speed, direction and position of the shaft rotation [20].

The rotary encoder is used in robot control that requires high accuracy in positioning such as Robot Mechanism, Omni Robot and Robot Tank. In addition to the robot, the rotary encoder can also be used in determining the direction and speed of the motor drive. The physical form of the Rotary Encoder is shown in Figure 10.

2.2. System design

2.2.1. Weather Monitoring System Design

In this weather monitoring systems can be grouped into three parts, the payload or payload, antenna tracker, and GUI as shown in Figure 11. When flown, the load reads atmospheric parameters namely temperature, relative humidity, air pressure, wind direction, wind speed, and altitude above sea level. Then the data that has been obtained by the charge is transmitted and then received by the antenna. The data is sent to a computer using a USB cable and displayed on the GUI. Because the data received by the ground station is still the raw

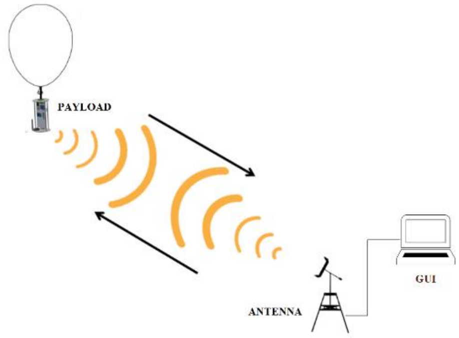

Figure 11 Weather Monitoring System Design

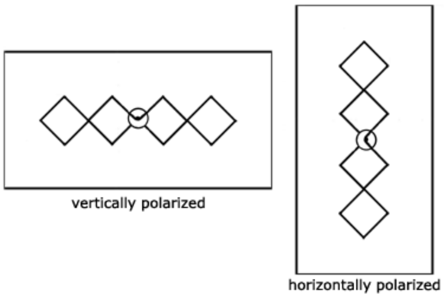

Figure 12 Double Biquad Antenna

data before it is displayed first computer data processing.

By using the data received by the computer calculates the azimuth and elevation angles to be used for the antenna to the charge. Calculation results in the form of angular data are then sent to the tracking antenna system (control unit) using a different serial connection automatically.

2.2.2. Antenna Design

In designing the antenna design, researchers used directional antennas. The directional antenna was chosen because the antenna can focus more on receiving data received by the antenna. Then the type of antenna used is a double biquad antenna, where the antenna is made of a closed-loop dipole wire with a square-shaped double show in Figure 12. Double biquad antenna is a modification or applying the basic design of a biquad antenna that only uses two quad (square) antennas [21] [22].

The biquad antenna has a ground plane gap which is located not too far from the dipole circuit to reduce radiation from the back. this also affects the gain and bandwidth values as shown in Figure 13. the smaller the ground plane gap, the gain value will be greater but the bandwidth value decreases. and also to reverse if the greater the value gap ground plane, the gain will be smaller and will widen the bandwidth values [22] [23]. The double biquad antenna also has a square reflector as shown in Figure 14. This reflector functions as a signal

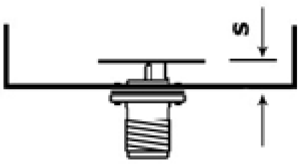

Figure 13 Ground Plane Gap

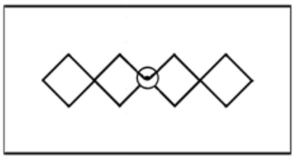

Figure 14 Reflector Double Biquad Antenna

receiver that receives the antenna to get a strong signal reception value [24].

Another purpose in making this double biquad antenna lies in the reflector used. Because as a signal amplifier the wider the reflector used, the more power will be received. The length and width used in making reflectors are 152.2 cm and 76.1 cm. Materials used in the manufacture of reflector antennas are wire netting (ram-ram) which has a value equal signal strength nice catch by using aluminium [24]. Another consideration for using this wire is to have a lightweight so that it does not overload the antenna and tracker antenna when moving.

2.2.3. Buffer Design

To generate maximum signal shot takes a suitable distance between the antenna and ground. this is needed so as not to cause signal loss when receiving data from the transmitter or transmitter.

Design buffer used is two buffer for the antenna and support for the body or feet from the antenna tracker. Buffer antenna serves as the support to stand. Antenna supports are also used as a container for the mechanical motor to move the antenna to the elevation angle. The width of the buffer that is used is 75 cm and the height between the legs or the supporting body is 70 cm. Design of antenna buffer can be seen in Figure 15.

The second buffer design that is used as a foot or body buffer used as the support of the entire antenna tracker to remain sturdy and will not be overturned when there is excessive shock, as well as the container cross-section of a motor mechanic and electrical circuit of the antenna tracker. This buffer is designed to use four legs with a square cross-sectional shape of the container. the height of the supporting leg is 160cm in length with 30 cm and 60 cm in cross-sections respectively. The body buffer can be seen in Figure 16.

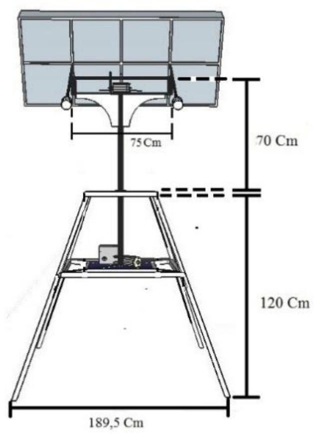

Figure 15 Antenna Buffer

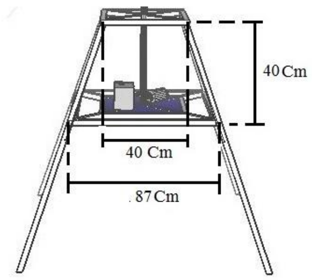

Figure 16 The Body Buffer of Antenna

2.2.4. Transmission System

Transmitter system is a system contained in the load. Which consists of Arduino Pro Mini as the main controller. There are three sensors used in the system is the sensor SHT31 as a reader of relative humidity and temperature parameters, sensor BMP180 as readers of air pressure parameters, GPS sensor reader Ublox Neo6 as the height and location of the cargo. The power source uses an 800mAh Li-Po 3 Cell battery. Before getting into Arduino Pro Mini there is a voltage regulator module UBEC which will change the voltage of the battery becomes 5volt making it safe for Arduino Pro Mini has a voltage input specification of 5volt. The data that has been obtained is then processed by Arduino Pro Mini and put together in one package in the form of a data string. Then the data is transmitted to the ground station using a module SV611 with 433Mhz radiofrequency. Design of the transmitter system circuit can be seen in Figure 17.

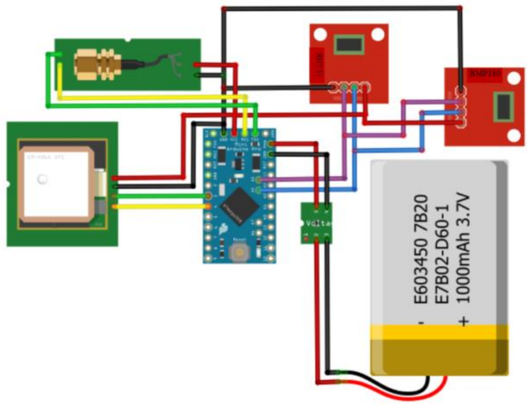

Figure 17 Transmitter System Circuit

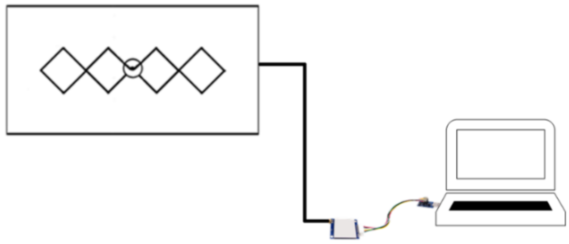

Figure 18 Receiver System

2.2.5. Receiver System

Data transmitted by the payload will be received by the Ground Station is connected to the antenna module SV651 with the same operating frequency is 433Mhz with SV611 module contained in the charge. SV651 modules that are connected in series with the computer will automatically send data to a computer that will be processed and displayed and stored by the GUI. Design of the receiver system can be seen in Figure 18.

2.2.6. Tracking System

A tracking system is a system that can move the antenna automatically follow wherever payload will move. The system uses an Arduino Mega 2560 as the main controller of the system. Arduino Mega 2560 will receive data in the form of Azimuth and Elevation angles sent by the GUI. The data that has been received is then processed by Arduino Mega 2560 and split into two, the azimuth angle to drive the dc motor so that the antenna can track horizontally and the elevation angle to move the stepper motor so that the antenna can track vertically. Design of a tracking system circuit can be seen in Figure 19.

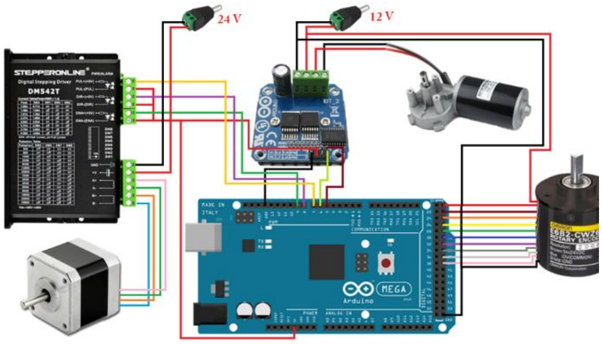

Figure 19 Tracking System Circuit

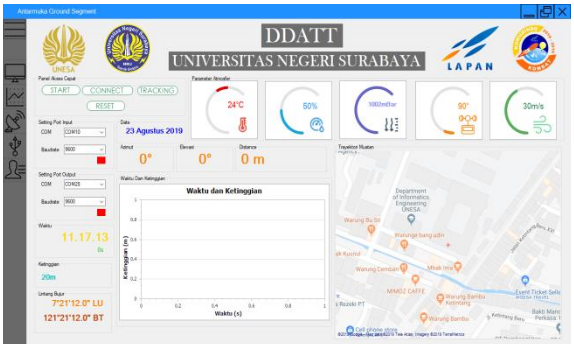

Figure 20 Parameters Display

2.2.7. Graphical User Interface

Data that has been received by the computer will be displayed and stored on a computer by the GUI (Graphical User Interface). Before the data is displayed, the GUI perform data processing that is solving the previously received data in the form of a data package of six data atmospheric parameters. After solving it, the GUI will display the data on a computer / laptop screen so that others can easily find atmospheric parameters in real time. Display of atmospheric parameters can be seen in Figure 20.

Atmospheric parameter data is also displayed in the form of two-dimensional graphs so that data from one another can be compared directly. The graph shows data such as height values comparison with temperature, altitude with relative humidity, altitude by air pressure, the height of the wind direction, and altitude winds. Graph display can be seen in Figure 21.

In addition, to display a parameter data and graphs in real-time, the GUI can display the location of the charge using a two-dimensional map so that loads can be monitored the moving wherever cargo is located. Location display can be seen in Figure 22.

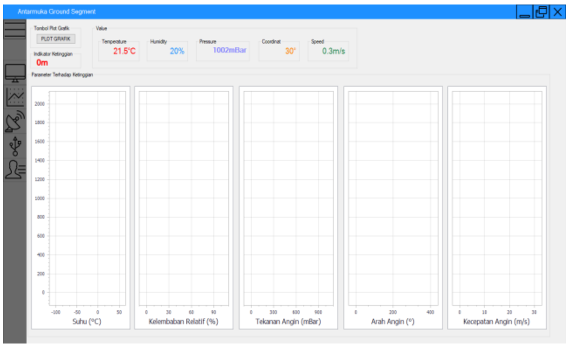

Figure 21 Graph Display

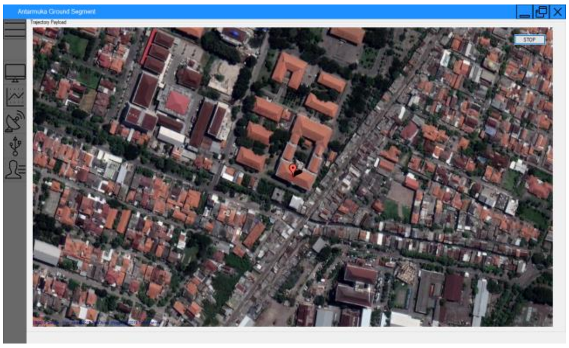

Figure 22 Location Display

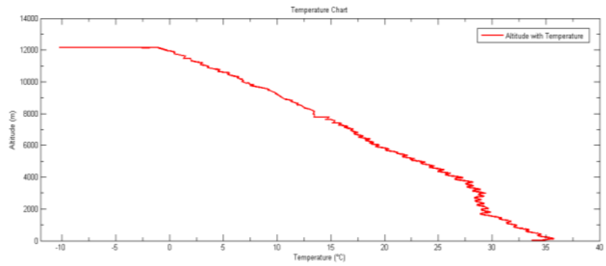

Figure 23 Temperature Chart

GUI can also store data on computer parameters so that any weather monitoring atmospheric parameters are recorded data in real-time that is saved automatically. Data is stored in .csv format that can be opened using Microsoft Excel.

3. RESULT AND DISCUSSION

Data were collected at the Air Force Base Pameungpeuk Garut in West Java by flying a cargo using a hot air balloon. After being flown the cargo successfully sends data and is received by the ground station. The system can send and receive data in real-time from cargo starting to be flown to a maximum height of 12170.1m above sea level. Also, the GUI managed to display atmospheric parameters in real-time and managed to store atmospheric data on personal computers.

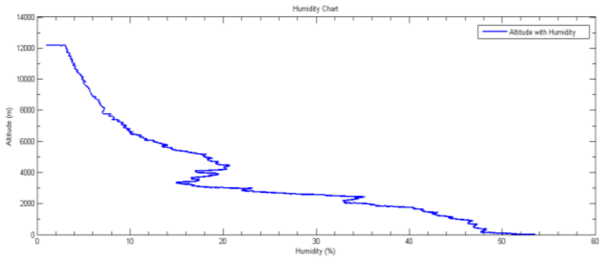

Figure 24 Humidity Chart

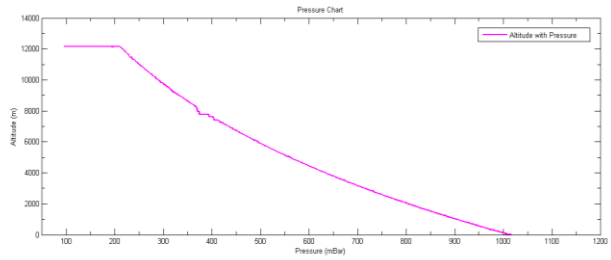

Figure 25 Pressure Chart

As shown in Fig. 23 when the payload starts flying at an altitude of 23.8m, the temperature value is 33.69 ° C. The temperature decreases with increasing altitude. The last temperature obtained with an altitude of 12170.1m is -10.27 ° C.

In Figure 24 it can be seen that the average humidity also decreases with increasing altitude. Obtained the value of humidity when the payload starts being flown by 53.47% with a height of 23.8m. The last humidity obtained was 1.08% with a height of 12170.1m.

Likewise, the air pressure shown in Figure 25, the higher the payload, the smaller the air pressure in the atmosphere. When the load is starting to be flown, the air pressure value is 1012.85mBar with a height of 23.8m. Obtained a final moisture value of 96.55mBar with a height of 12170.1m.

Figure 26 shows that the direction of the wind changes rapidly. When the charge is flown in the direction of the wind by 182 ° with a height of 23.8m. When the height of 12170.1m wind direction is 310 °. Likewise, also with changes in wind speed that changes rapidly during the load is flown. When the initial charge is flown, the wind speed of 0.09 m/s with a height of 23.8m is obtained and obtained a speed of 6.99 m/s with an altitude of 12170.1m.

4. CONCLUSION

The main objective of this research is to develop and implement a weather monitoring system with a tracker antenna using SV611 and SV651 modules at a frequency of 433Mhz.

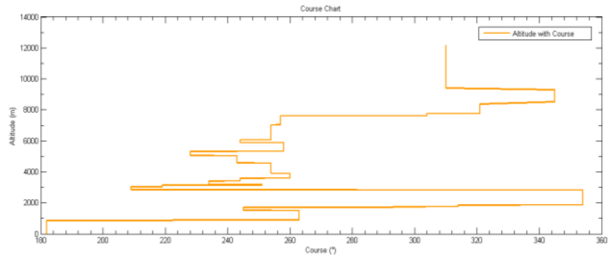

Figure 26 Course Chart

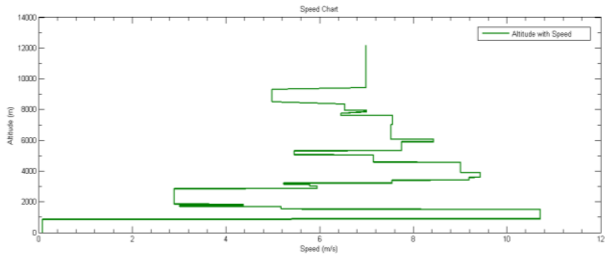

Figure 27 Speed Chart

From the results obtained during tests and experiments conducted, it can be concluded: 1) The system is able to send and receive data in real time at an initial height of 23.8m to a maximum height of 12170.1m. 2) The system succeeded in getting atmospheric parameter data needed for weather observations in the Troposphere (6-10 Km) to Tropopause (10-20 Km) because this atmospheric layer is the most influential on weather conditions on the earth's surface [3]. 3) Antenna tracker can move to the position of the charge wherever the load is located by knowing the azimuth and elevation angle to an altitude of 12170.1m above sea level. 4) GUI is able to display atmospheric parameter data in real time and store it on a personal computer.

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